Dose Analysis of Remediation of the Former D&G Operating Company's Evans Well #1 Site Located in Winnie, Texas

October 2007

Ruben Cortez, Thomas Cardwell
Texas Department of State Health Services
Inspection Unit, Radiation Branch

## Summary

Department of State Health Services staff developed a RESRAD 6.3 model for former D&G Evans Well No. 1 site in Winnie, TX. The deterministic model showed the highest dose to public to be in the first year due to exposure from vegetation (water independent) intake. This intake resulted in a 2.81 mrem/yr total effective dose equivalent (TEDE) to the critical group. A probabilistic analysis was also performed on non-nuclear variables using distributions given in NUREG/CR-6697 "Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes." Also, from document CR-6697 the distribution for the soil/water partition coefficients ($K_d$) for Americium in Contaminated, Saturated and Unsaturated zones were used resulting in a calculated mean dose of 2.43±0.061 mrem/yr and a 95th percentile dose of 7.05±0.46 mrem/yr at the time of the max dose.

For the majority of parameters the RESRAD default values for resident farmer scenario were used. Some of the key parameters changes follow: area of the contaminated zone, 4,000 meters (m) squared was used based on 70.7 m diameter circle, from ARS survey and Corrigan Consultants proposal to perform baseline radiological characterization of Evans Well #1 site was on a 50m by 50m grid area; the dose limit to the public of 25 mrem/yr from Title 25 Texas Administrative Code (TAC) §289.202; a thickness of one meter was used for contaminated zone since ARS survey indicated potential of contamination greater than 18 inches (0.5 m). Staff used the thickness of one meter since the dose change at a greater value was insignificant, however; the dose did decrease with greater thicknesses at lower values (Attachment 4); the runoff coefficient of 0.4 was used since Winnie is an agricultural area located in flat costal plains, though this value had little correlation to the final dose; initial contamination level for the principle radionuclide, americium-241, was chosen as 6 picocuries per gram base on the release criteria agree to in the Quality Assurance Project Plan for the Remediation of the Former D&G Operation Company's Evans Unit No. 1 Wellsite located in Winnie, TX signed on May 25, 2007 (QAPP).

The most significant variations from the RESRAD default values were the contaminated, unsaturated, and saturated zone distribution coefficients ($K_d$) for americium that were used. This value was 1,445 $cm^3/g$ based on the mean from lognormal distribution given in table 3.9-1 in NUREG/CR-6697. The user's manual for RESRAD version 6 indicated $K_d$ for americium can vary from 990 to 9,600 cm3/g with default value of 20 cm3/g. Using the default $K_d$, the deterministic model calculated a max dose of about 22.5 mrem/yr.

# (Background) Introduction

Site Information/Location

On August 11, 1995, a three curie americium-241/beryllium (AmBe) radioactive logging source became stuck in Well No. 1 at the D&G Operating Co., Inc. No. 1 Evans Unit well site 1.5 miles north of Winnie, Texas in Chambers County. During the recovery phase, the logging source ruptured resulting in contaminating the well, associated equipment, and surface soil. The logging source was recovered and transported to the Department of Energy (DOE) for evaluation. The DOE determined that approximately 1- 1.5 curies (Ci) of the source material had been recovered. A fence was subsequently constructed around a rectangular area of the well site approximately 130 feet by 115 feet, which included the well and the area of known contamination. A Site Map is shown in Attachment 1.

The Texas Railroad Commission Oil and Gas Division (the Commission) contracted Energy Solutions to excavate and remove contaminated material from the site in order to release the area for unrestricted use in accordance with State of Texas Department of State Health Services (DSHS) requirements. Energy Solutions agreed to; (1) removal and disposal of contaminated liquids,(2) removal and disposal of dry active waste (DAW), (3) removal and disposal of contaminated soil with concentrations of Am-241 greater than 6 picocuries per gram (pCi/g) in accordance with Title 25 Texas Administrative Code (TAC) §289.202 (eee), "Limits for Contamination of Soil, Surfaces of Facilities and Equipment and Vegetation." [The limiting values are found in 25 TAC §289.202 (ggg)(8)], and (4) backfilling excavated areas with clean fill soil upon meeting all remediation criteria and after obtaining approval from the Railroad Commission of Texas. As part of the remediation and release of the area, the Commission has contracted a third party, Corrigan Consultants to perform a radiation confirmation survey. Energy Solution's initial radiological survey of site performed to assess amount of contamination at the D&G Well site covered a 50 meter (m) square area around the well head. In addition several samples where taken outside the contaminated area.

# Radiological Dose Estimate Factors for Site

Method and Assumptions

**Dose Conversion Factor**

Dose Conversion Factor (DCF) used are from Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion." The food transfer factors and slope factors are from Federal Guidance Report 13, "Cancer Risk Coefficients for Environmental Exposure to Radionuclides," published in 1999 (FGR 13 Morbidity). The slope factors used are based on FGR 13 morbidity values these DCFs are accepted by EPA for radiation risk assessment.

**Dose Limit to Public, Time since initial placement and times for Calculations**

The dose limit to general public use is 25 mrem/yr based on requirement in Title 25 Texas Administrative Code (TAC) §289.202(ddd)(2) **Radiological requirements for unrestricted**

**use** states, "*A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are ALARA*. This value corresponds to the value in Title 10 Code of Federal Regulations (CFR) 20."

The more restrictive resident farmer scenario was chosen as the critical group for dose assessment in the RESRAD model. In the resident farmer scenario, a family is assumed to move onto the site after it has been released for use without radiological restrictions, build a home, and raise crops and livestock for family consumption. Members of the family can incur a radiation dose by (1) direct radiation from radionuclides in the soil, (2) inhalation of resuspended dust (if the contaminated area is exposed at the ground surface), (3) inhalation of radon and its decay products, (4) ingestion of food from crops grown in the contaminated soil, (5) ingestion of milk from livestock raised in the contaminated area, (6) ingestion of meat from livestock raised in the contaminated area, (7) ingestion of fish from a nearby pond contaminated by water percolating through the contaminated zone, (8) ingestion of water from a well or pond contaminated by water percolating through the contaminated zone, and (9) ingestion of contaminated soil.[1] All of the defaults for this scenario were used including occupancy, dietary and non-dietary ingestion, and storage times.

The time lapse since placement of material is assumed to be zero since average concentration of the contamination is know at the time of completion of the remediation. Time of the model used is 1,000 years, §289.202(ddd)(1)(D) requires that when calculating TEDE to the average member of the critical group, the licensee shall determine the peak annual TEDE dose expected within the first 1,000 years after decommissioning. Calculation times in RESRAD went out to 1000 years with intermediate calculations performed at one, three, 10, 30, 100, and 300 years.

**Contaminated Zone Information**

The area of the contaminated zone, 4,000 $m^2$ is used based on 70.7 m diameter circle, from ARS survey and Corrigan Consultants proposal to perform baseline radiological characterization of Evans Well #1 site was on a 50m by 50m grid area. Depth of contaminated area assumed a worst case of the entire area contaminated to 18 inches or about 0.5 meters. The one meter depth used in RESRAD was due to the fact that the dose decreases with less depth but did not increase significantly at depths greater that one meter. Length parallel to aquifer left at default value of 100 meters about (328 ft), though calculated to be just slightly over 70m since it did not affect the total dose.

The concentration of the radionuclide used was 6.0 picouries per gram (pCi/g). This value corresponds to the value listed in table of 25 TAC §289.202(ggg)(8) "Soil Contamination Limits for Selected Nuclides." The Texas Railroad Commission used this concentration limit for the release criteria for the decommissioning of the site and the value was in agreement

[1] Yu, C. et al. Users Manual for RESRAD Version 6, July 2001, p. 2-16

with Energy Solutions QAPP. An average concentration of 2.3 pCi/g was calculated from data in Energy Solution's Project Final Report for the site after completion of remediation. Staff chose the worst case scenario with no cover resulting in the most conservative dose estimate.

**Hydrological Data**

The majority of the Hydrological factors were kept at the default values. Although, it is known that the soil composition for the well site area is Morey Silt Loam, a soil type whose parent materials are loamy and clayey sediments of the Beaumont formation, the defaults where considered to be the most conservative. Inspection unit staff used a soil/water partition coefficient ($K_{d)}$ for Americium of 1445 cm3/g for calculations. This value is the median value for $K_d$ from NUREG/CR-6697. This $K_d$ was use since the values listed in the RESRAD User Manual can range from 900 to 9,600 $cm^3/g$ with the default value a very low 20 $cm^3/g$. A $K_d$ greater than 1000 $cm^3/g$ does not significantly affect the dose. Noticeable affects due to $K_d$ where noted in the contaminated zone but not the saturated or unsaturated zones.

The run off coefficient from Table 1 Yu et al. RESRAD user manual for Agricultural environment:

$$Cr = 1 - c_1 - c_2 - c_3 = 1 - 0.3 - 0.2 - 0.1 = 0.4$$

$c_1 = 0.3$ for Flat land with average slopes of 0.3 to 0.9 m/ mi
$c_2 = 0.2$ for Intermediate combinations of clay and loam
$c_3 = 0.1$ for cultivated lands

Average precipitation for Houston area (1.17 meters/yr) was considered but was very close to the default value of one meter. The default rainfall was used since the default was more conservative. Similarly, the Winnie area average wind speed ranges from 3-5 m/s but the more conservative default wind speed of 2 m/s was used. The Saturated Zone and Unsaturated Zone default factors where used primarily because of the low correlation to the final dose.

Results and Discussion

Attachment 6 is the RESRAD model summary for D&G Evans Well #1 site in Winnie, TX. The deterministic model calculated the highest dose to public to be at initial time due to exposure from Plant (water independent) intake. This resulted in a total dose of 2.81 mrem/yr in the first year. The uncertainty analysis was also performed on non-nuclear variables using distributions given in NUREG/CR-6697 "Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes." In addition, the CR-6697 distribution for $K_d$ for Am-241 in Contaminated, Saturated and Unsaturated zones were used resulting in a mean dose of 2.43±0.061 mrem/yr and a $95^{th}$ percentile dose of 7.05±0.46 mrem/yr at the time of the max dose.

The deterministic model using default $K_d$ and average concentration of 2.3 μCi/g for americium-241 resulted in a calculated maximum dose of 22.6 mrem/yr at year 321.

References

Energy Solutions, Project Final Report for the Former D&G Operation Company's Evens Unit No. 1 Wellsite, August 2007

Chesapeake Nuclear Services, Inc., Review of Energy Solutions Baseline/ Confirmation Survey Supplement 1, July 2007

Energy Solutions, Quality Assurance Project Plan for the Remediation of the Former D&G Operation Company's Evens Unit No. 1 Wellsite located in Winnie, TX, May 2007

Chesapeake Nuclear Services, Inc., Investigation Work Plan and Final Status Survey WCS Drain Fields (Radiological Survey and Sampling), October 2005

Title 25 Texas Administrative Code §289.202, effective date April 2002

Title 25 Texas Administrative Code §289.256, effective date September 2004

Yu, C., et al. Data Collection Handbook to Support Modeling the Impacts of Radioactive Materials in Soils, April 2001.

Yu, C. et al. Users Manual for RESRAD Version 6, July 2001

Yu C. et al. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes, NUREG/ CR-6697, December 2000

Kathren, Ronald L. Radioactivity in the Environment Sources, Distribution and Surveillance, 1984

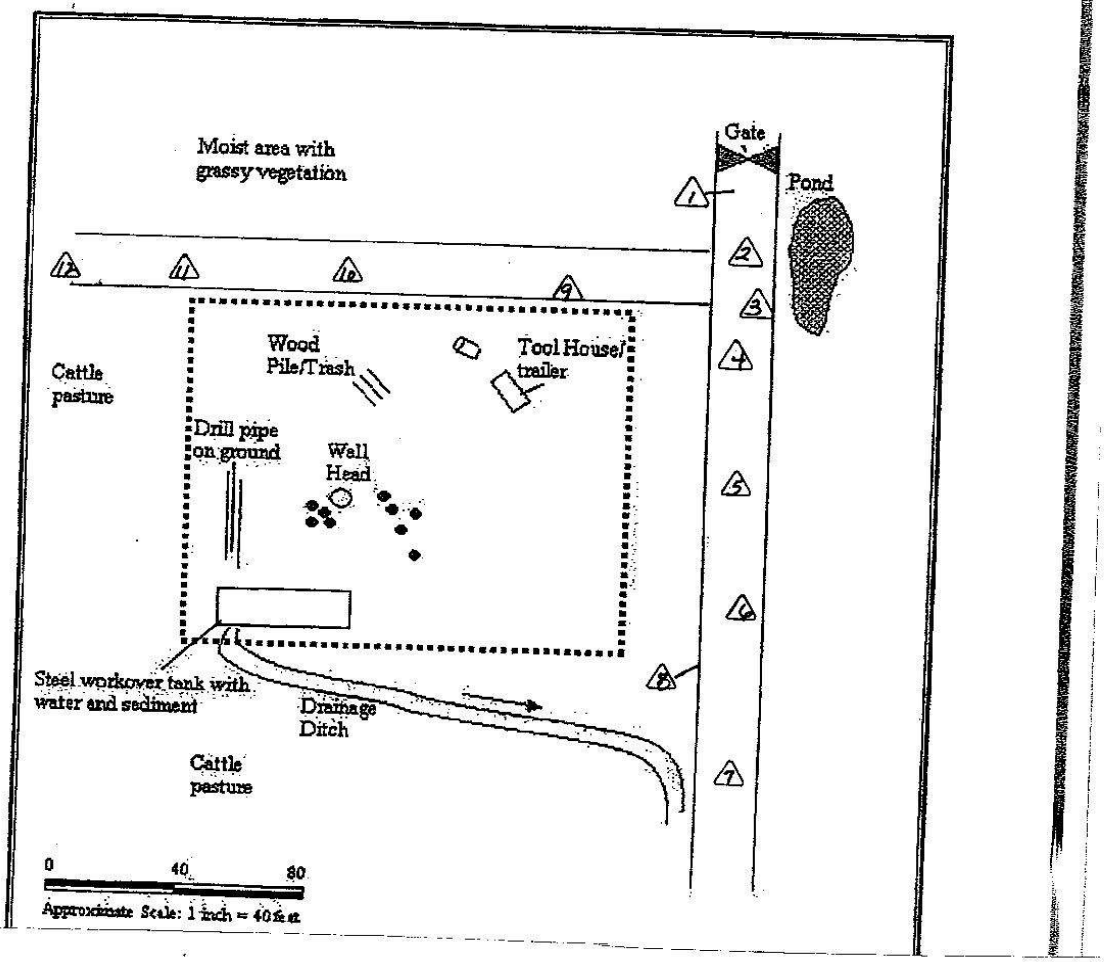
Anspaugh, Lynn R et al. Movement of Radionuclides in Terrestrial Ecosystems by Physical Processes. Health Physics Vol. 82 No. 5 pgs 669-679, May 2002

Eckerman, K, Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion", EPA-5201/1-88-020, 1988

Eckerman, Keith et al., Federal Guidance Report No. 13 EPA 402-R-99-001 September 1999

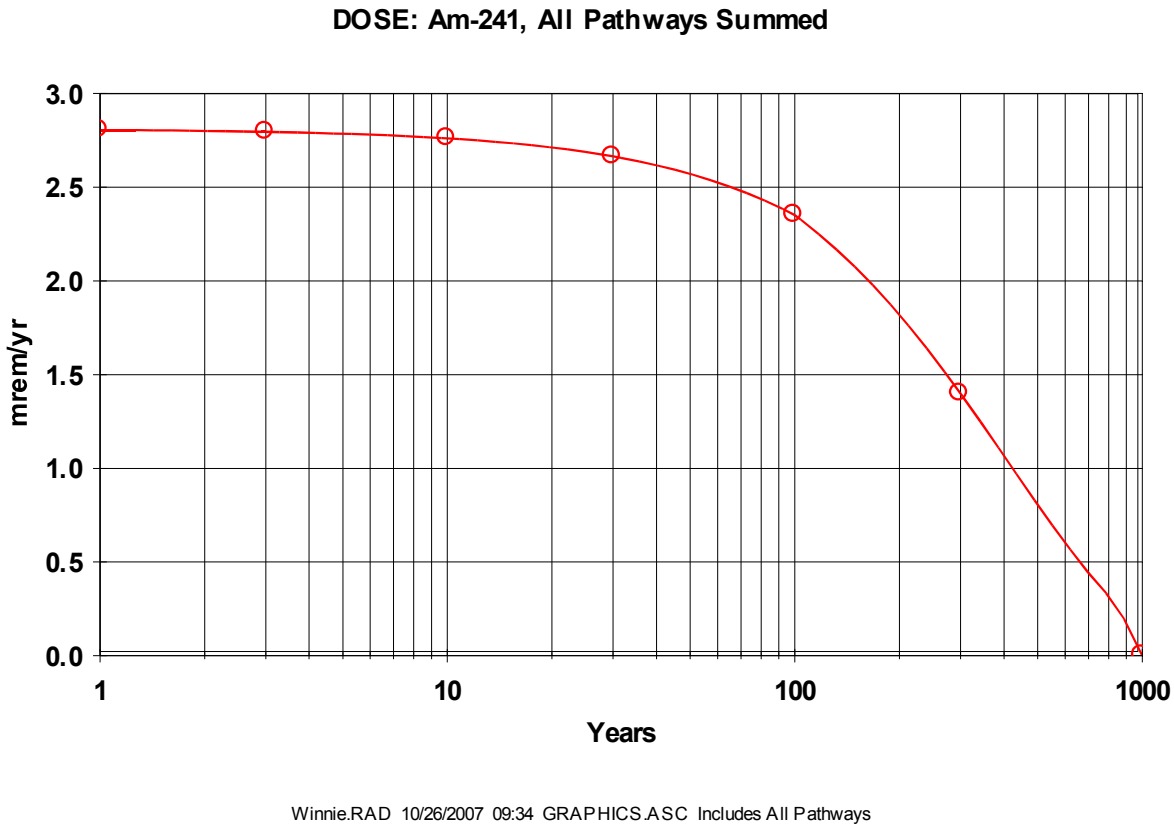
Crenwelge, Gerald, Natural Resources Conservation Service, Soil Survey of Jefferson and Orange Counties, Texas, 1994

Attachment 1 – Site Map

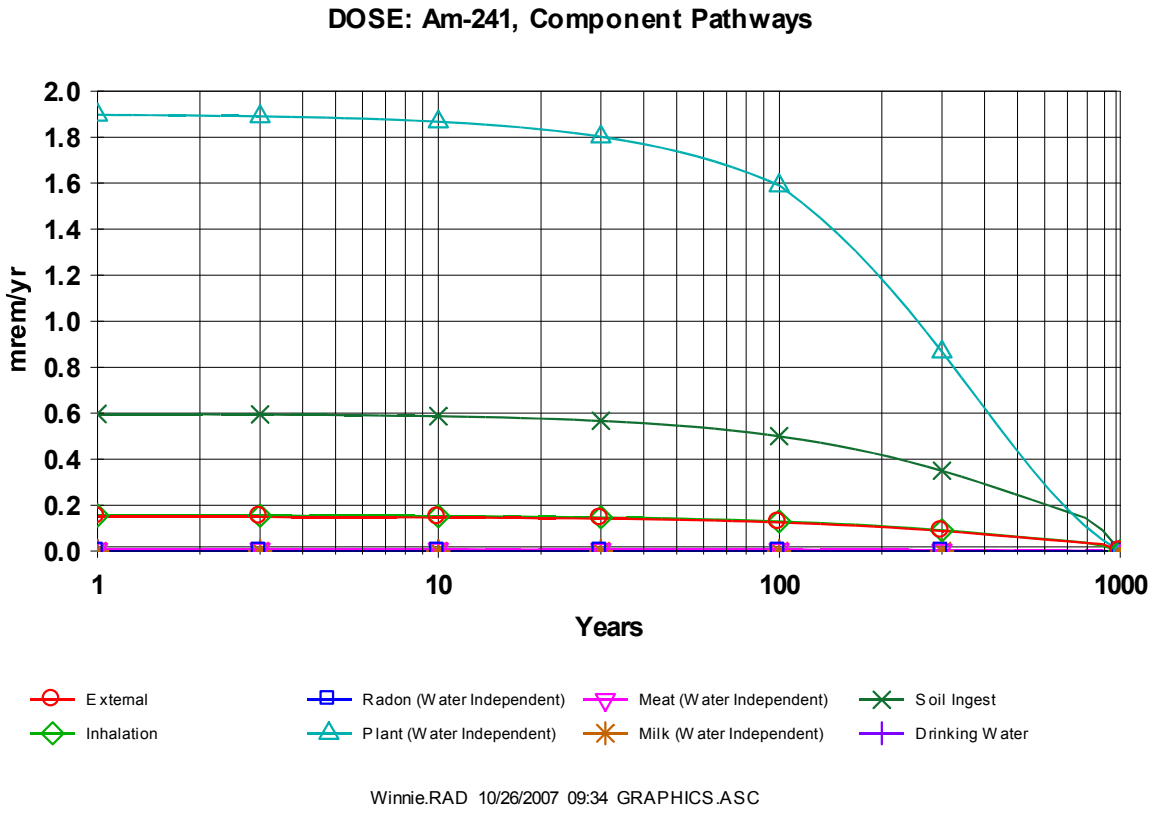



⚠ - indicates soil sample locations prior to road being put down.

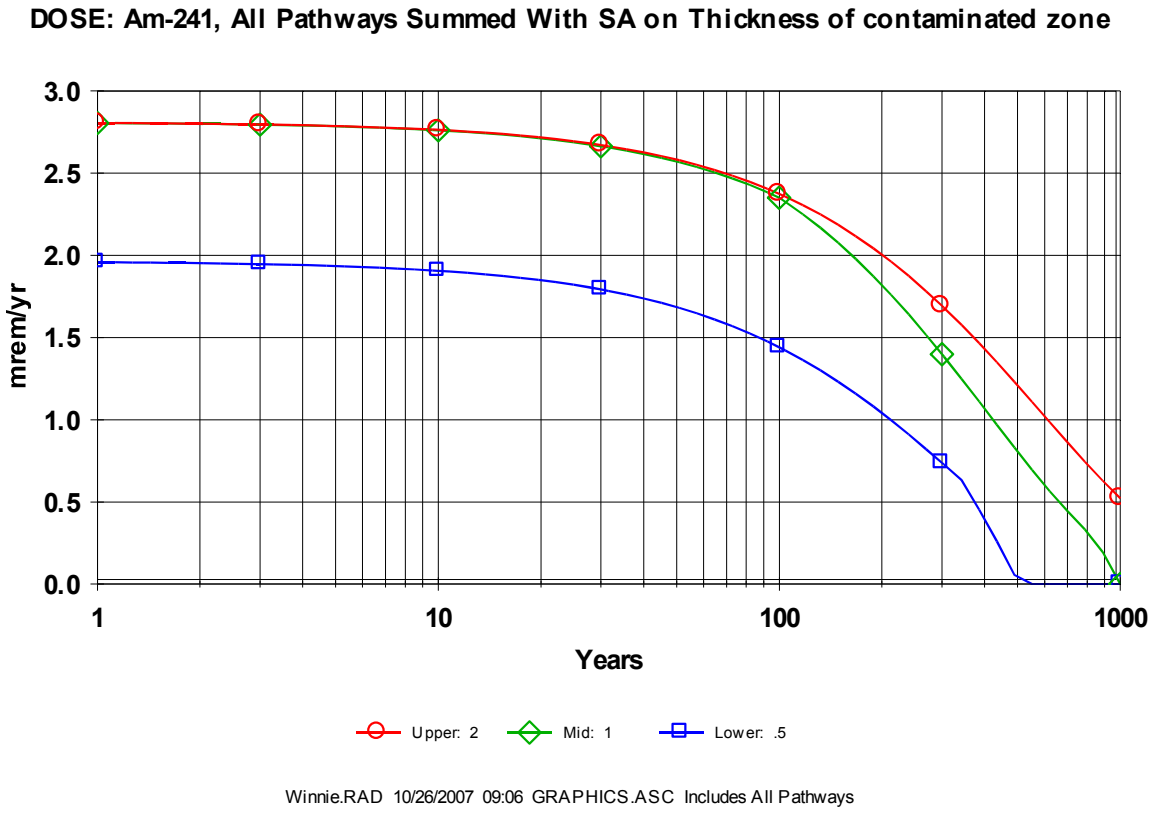
Attachment 2: Graph of Deterministic RESRAD model



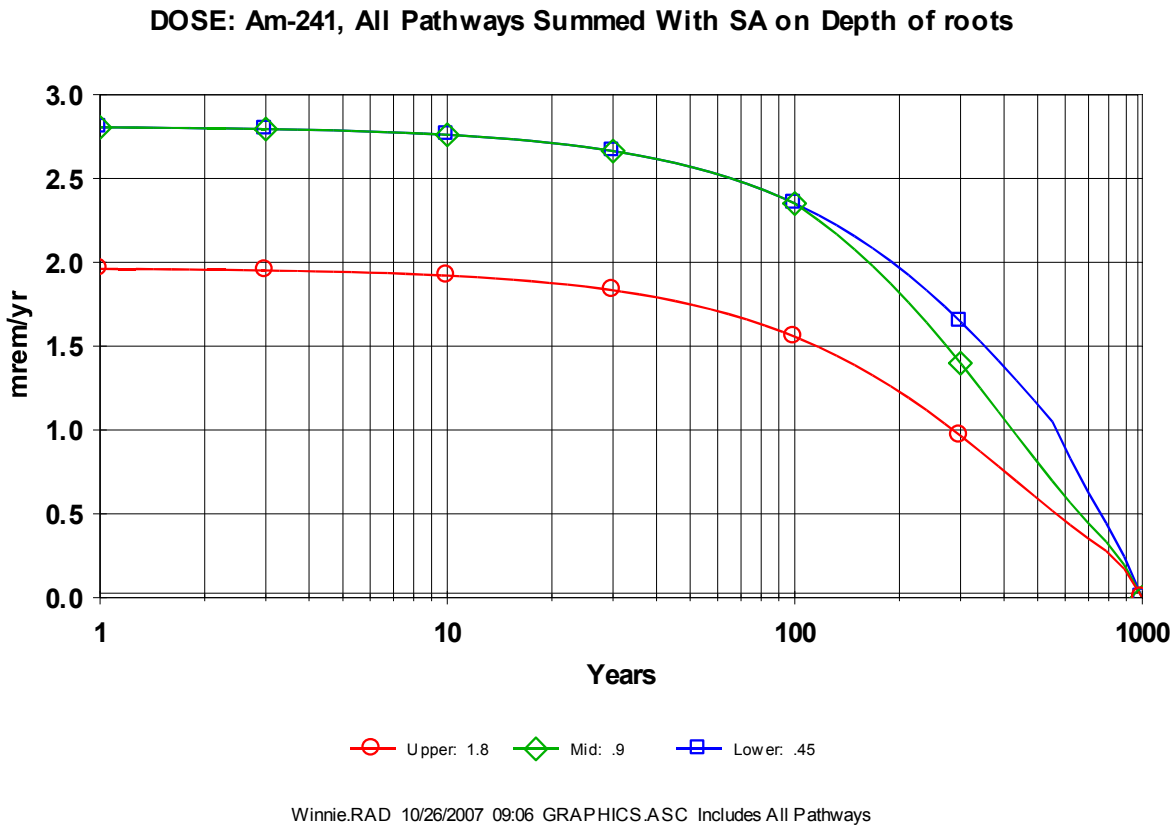
Attachment 3: Graph of RESRAD deterministic model component Doses



Attachment 4: Sensitivity analysis for thickness of contaminated zone



Attachment 5: Sensitivity analysis for depth of roots



Attachment 6 Deterministic RESRAD Summary